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STATUS OF THE ESA EARTH OBSERVATION MISSIONS

CGMS is informed of the status of the European Space Agency Earth Observation missions. Two of them, MSG and Metop have been developed in co-operation with EUMETSAT. The second ERS satellite, launched in 1995, is currently in operation. Envisat and MSG-1 were successfully launched in 1st March and 29th September 2002, respectively. Earth Explorer and Earth Watch missions are undertaken under the so-called Envelope Program, a rolling program designed to underpin European efforts in EO from space. The Earth Watch program includes, since January 2002, the Global Monitoring for Environment and Security (GMES) services element .

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1. - INTRODUCTION

The Earth Observation Programs Directorate of the European Space Agency (ESA) is currently developing and operating a number of satellite programs. Two of these, Meteosat Second Generation (MSG) and Metop, have been developed in co-operation with EUMETSAT. The second ERS satellite, launched in 1995, is currently operational. The Envisat satellite was successfully launched 1st March 2002 while MSG-1 was launched by EUMETSAT on 29th September 2002, both from Kourou in French Guiana. The research-oriented Earth Explorer and the initial phases of the Earth Watch missions oriented towards operational services are undertaken under the so-called Earth Observation Envelope Program, a rolling program designed to underpin European efforts in EO from space. The Earth Watch program includes since January 2002 the Global Monitoring for Environment and Security (GMES) services element.

2. - STATUS OF THE ERS MISSIONS

The ERS-1 spacecraft, which ceased its operations in March 2000, is regularly tracked to predict and avoid possible interference with the orbits of other missions. All ERS services are provided by ERS-2, which remains operational. All LBR instruments are operated on a global basis, SAR in response to user requests with an average duty cycle of some 4 to 5 minutes per orbit. All LBR and SAR data with the exception of WSC and ATSR HR data are distributed nominally.

The Platform, Payload and the Instrument Data Handling and Transmission (IDHT) system have been working nominally and despite the advanced mission lifetime no significant aging has been observed. Special effort has been dedicated to recover the attitude stability, assuring the quality of the data products, somewhat degraded since January 2001, following problems on the Gyroscopes. The Attitude and Orbit Control System (AOCS) was operating in Extra Back-up Mode (EBM) until the beginning of June, when the Zero Gyro Mode (ZGM) was loaded and activated on-board ERS-2. The commissioning of the ZGM lasted until end July. During this month the pointing performances of the satellite have been analyzed and the results are exceeding the objectives.

Further improvements for the yaw pointing accuracy were made until end of September 2001. The ZGM operations are very promising for further long operational lifetime of the spacecraft.

3. - STATUS OF THE ENVISAT PROGRAM

The ENVISAT satellite was successfully launched by Ariane 5 on 1st March 2002. The solar array deployment and the attitude acquisition were performed within less than 90 minutes of

launch. The satellite reached its final orbit on 3rd April and is since then positioned on its assigned 35 days repeat cycle, 30 minutes ahead of ERS-2; both satellites are controlled to overfly the same ground track, within 1 km.

The Launch and Early Orbit Phase was completed on schedule: by 4th March 2002, the ASAR antenna deployment was completed and the Artemis Ka Band antenna mast was deployed on 7th March 2002.

All 10 instruments were activated by mid April. The calibration activities have been initiated immediately after the instrument activations, with data continuously recorded on board and dumped over the ESA Kiruna station, as well as real time ASAR and MERIS data received at the ESA Matera and Kiruna stations. This scenario permits the recovery of the full global mission data, pending the availability of the ARTEMIS data relay satellite expected to reach its final geostationary orbit by February 2003.

All instrument modes have been tried out since April and very stable performances have been observed with all of them. Most of the instrument processors have been already updated to reflect the specific characteristics observed in orbit and to prepare for the product release to users.

While significant progress has been achieved in the robustness of the payload data segment, allowing in particular delivery of the data products needed for calibration activities, a plan including the setting up of a back-up station in Svalbard to accommodate the current lack of Artemis data relay facilities, has been put in place to perform over the last quarter 2002, the validation and operational developments needed to reach operational readiness of the mission by end 2002.

The calibration activities have been completed on schedule and the Calibration Review was successfully held in September at ESTEC. Based on these results, the progressive opening of the services to users, beyond the Cal/Val teams, has been initiated mid September. This gradual phasing in of users, including over 700 research projects, will continue to take place over the last quarter 2002. Over this period, priority is maintained to servicing the Cal/Val Teams in order to provide them with the data products in time for preparing the Validation Workshop scheduled for December at ESRIN.

The first results generated during the Commissioning Phase activities show the great potential of the Envisat mission. Some of them can be seen within the Envisat web site (http://envisat.esa.int); the web site gives also access to data catalogues, data handling tools and sample products.

4. - STATUS OF THE EARTH EXPLORER MISSIONS

4.1 – Scope of the Earth Explorers

The Earth Explorers are research-oriented space missions tackling critical Earth science issues. There are two types of such missions, subject to different financial limits and programmatic functions i.e.

- *Opportunity* Missions designed to be a fast and flexible response to a single critical scientific issue and subject to strong financial (<110 MEURO) and development constraints (30 months for phase C/D).
- *Core* Missions, < 400 MEuro, more complex and larger in scope, which must tackle a range of fundamental problems of wide community interest whilst remaining well focused. They are supported by a wide (international) community of scientists.

The financial limits only relate to the ESA contribution, but the Earth Observation Envelope Program is designed to encourage international co-operation. In the context of international co-operation, a *Core* mission would normally be led by ESA, but can include important contributions from partner Agencies.

In the past years, four missions have been selected for implementation, namely two *Core* missions:

GOCE (Gravity and steady-state Ocean Circulation Explorer)
ADM-Aeolus (Atmospheric Dynamics Mission)

and two *Opportunity* Missions, selected from a total of 27 proposals:

- Cryosat (Polar Ice Monitoring)
- SMOS (Soil Moisture and Ocean Salinity)

A third mission ACE (Atmospheric Climate Experiment), consisting of a constellation of micro-satellites with GNSS atmospheric sounding receivers, is maintained as a hot stand-by mission to replace either of the above if unforeseen problems were encountered.

4.2- GOCE

The aim of the GOCE mission is to provide global and regional models for the Earth's gravity field and for the geoid, its reference equipotential surface, with high spatial resolution and accuracy. Such models will be used in a wide range of research and application areas, including global ocean circulation, physics of the interior of the Earth and leveling systems based on GPS.

The mission responds to the requirements put forward by many international scientific programs and initiatives such as WOCE, CLIVAR and GOOS. It is designed for the determination of an accurate description of the ocean dynamic topography and, thereby, the

mean ocean circulation, as an essential complement to the precise monitoring of ocean temporal variability already provided by altimetry.

The gravity vector cannot be measured directly in orbit, but can be inferred from other observations. The GOCE carries a gravity gradiometer that measures gravity gradients and GNSS (Global Navigation Satellite Systems) receivers for precise satellite position.

4.2.1- GOCE project status

The GOCE Space Segment development has achieved the last Phase B milestone represented by the successful conclusion of the GOCE Preliminary Design Review (PDR) and, consequently, the phase C/D has been kicked-off.

The subcontractor selection process has been almost completed with only few equipment suppliers to be confirmed by successful completion of the negotiations. The microthruster technology has been selected with FEEP (Field Effect Electric Propulsion) as baseline.

Equipment PDRs are taking place in order to release the detailed designs of the equipments as well as the development of the engineering and qualification models.

The Ground Segment Requirement Review is currently ongoing. Pending its successful completion the development of the ground segment elements will be initiated.

The launch is foreseen for February 2006.

4.2.2- GOCE science

Preparation activities for the definition of the Level 1 to Level 2 processing architecture as well as for the consolidation of the interfaces with the Level 1 output and with the users have been carried out. The organization of the development of the Level 1 to Level 2 processor is currently in preparation.

4.3- ADM-Aeolus

The scope of the Atmospheric Dynamics Mission, Aeolus, is to demonstrate the possibility of providing observations of winds at arbitrary altitudes in clear air. This will help to correct a major deficiency in the current (meteorological) operational observing network. The data will be assimilated into Numerical Weather Prediction models. The mission will also provide data needed to address some of the key concerns of the World Climate Research Program i.e. quantification of climate variability, validation and improvement of climate models and process studies relevant to climate change. The data will help as well to accomplish some of the objectives of the Global Climate Observing System, by contributing directly to the study of the Earth’s global energy budget by measuring wind fields globally in clear air. It will further provide information for the study of global circulation and related features such as

precipitation systems, El Niño and the SO phenomena and stratospheric/tropospheric exchange.

The main space element of the ADM is the ALADIN instrument i.e. a Doppler wind Lidar intended to provide profiles of the tropospheric wind above or in absence of thick cloud.

4.3.1- Aeolus Project Status

The contract for Phases B/C/D and E1 of the Aeolus satellite was kicked off on 1 July 2002. Launch is scheduled for October 2007.

The contract is initially with Astrium UK as Prime contractor, Astrium Toulouse as supplier of the instrument, and Astrium Friedrichshafen responsible for platform electrical subsystems. Further subcontractors will be selected prior to the start of Phase C/D in September of next year.

The construction of a Pre-Development Model of the instrument is well underway. Test results of the PDM receiver are expected in mid 2003, and the first tests of this receiver with a development laser looking upwards into the atmosphere are expected at the end of 2003.

During the Phase B two competing contractors have been building and testing Laser Test Beds. These LTBs have now reached a sufficient state of maturity that the Agency and the satellite prime contractor are confident that a laser with adequate output energy can be delivered operating in the so-called "burst" mode.

Another parallel activity has been to provide some early evidence of the effect of different kinds of stress on the operating lifetime of the pump diodes used in the on-board lasers. Conclusions are currently being drawn from this work and will be used to define the pump dioide qualification process.

4.3.2 Aeolus Science

Preparation for the Mission is being performed with support from a Mission Advisory Group of experts external to the Agency. Meteorological Agencies are well represented at this group. These include ECWMF, EUMETSAT, NOAA and various European National Meteorological Agencies. Other relevant scientific disciplines are represented and relevant technological advice is also available from the MAG.

Campaigns of ground and airborne validation using an Aladin Airborne Demonstrator are being actively planned in conjunction with the DLR.

Discussions have started on planning for experimental assimilation of Aeolus data after in orbit commissioning of the satellite.

4.4- CRYOSAT

The goals of CryoSat are to measure fluctuations in marine and land ice mass fluxes within the limit set by natural variability. Predicting future climate and sea level depends on knowledge of such fluctuations, while present observations are deficient in time and space. CryoSat and International Programs will provide a decade of focused study of the roles of the cryosphere.

The technical concept consists of a single spacecraft in a high inclination (92 degree) orbit, carrying a Ku-band altimeter, measuring altitude with detailed precision, capable of operating in conventional pulse limited mode, synthetic aperture mode and interferometric mode.

4.4.1 Project status

The CryoSat programme has now entered in the core of the C/D phases. The development is considered nominal. Activities concerning the space segment, the launcher and the ground segment are progressing smoothly in parallel without noticeable difficulties.

For the satellite development, the Prime Contractor (Astrium GmbH) is now preparing for the assembly of the "satellite test bed" which will allow undertaking a large number of verifications prior to start the integration of the Proto-Flight Model elements. In fact, the manufacturing phase is well advanced for a number of equipments. Some of them have been already delivered to the Prime Contractor.

The development of the Ground Segment is progressing nominally: At the European Space Operations Centre (ESOC, in Darmstadt-D) a dedicated review of the requirements applicable to the whole Ground Segment has been successfully held in late 2001. Concerning the Payload Data Segment (PDS), the development is under the responsibility of ACS (I). This includes also the Instrument Processing Facility. Implementation of algorithms for the level 1b is in progress. Concerning level 2 algorithms, a definition study has been initiated.

Following a competitive tender, Rockot has been selected as the CryoSat launcher. The launch will take place from Plesetsk. It is now scheduled for end June 2004.

4.4.2 CRYOSAT Calibration and validation activities (CAL/VAL)

The CryoSat Scientific Advisory Group (CSAG) has met at regular intervals and set-up the basis for the Announcement of Opportunity for Calibration/Validation activities. More than 30 scientific groups from 13 countries have responded to this announcement. A first meeting took place late September 2002 with representatives of the sea-ice and land-ice community. A final agreement on a consolidated Calibration/Validation plan is expected to be reached in December 2002

In the frame of CryoSat pre-launch activities, a joint ESA/NASA flight campaign involving simultaneous laser and radar altimeter measurements has been performed over the Greenland ice sheet in May 2002.

4.5- SMOS

In spite of the fact that both Soil Moisture (SM) and Sea Surface Salinity (SSS) are used in predictive atmospheric, oceanographic, and hydrologic models, to date, no capability exists to measure directly and globally these key variables. The main objective of SMOS is to deliver a crucial variable of the land surface: SM as well as SSS fields.

Over land, water and energy fluxes at the surface/atmosphere interface are strongly dependent upon Soil Moisture (SM). Evaporation, infiltration and runoff are driven by SM while soil moisture in the vadose zone governs the rate of water uptake by vegetation. Soil moisture is thus a key variable in the hydrologic cycle. For the oceans, Sea Surface Salinity (SSS) plays an important role in the northern Atlantic sub-polar area where intrusions with a low salinity influence the deep thermohaline circulation and the meridional heat transport. Variations in salinity also influence ocean near-surface dynamics in the tropics where rainfall modifies the buoyancy of the surface layer and the tropical ocean-atmosphere heat fluxes. SSS fields and their seasonal and interannual variabilities are thus tracers and constraints on the water cycle and on the coupled ocean-atmosphere models.

Low frequency microwave measurements (around 1 GHz) offer a unique means to achieve such goals. At such wavelengths, the measured signal is directly related to the brightness temperature of the surface (negligible atmospheric contribution), which in turn, through the emissivity, is directly linked to the dielectric constants of the target (i.e., moisture or salinity). Actually, the sensitivity of brightness temperature to soil moisture and salinity is optimum in the L band (1.4 GHz). The mission should also deliver information on surface temperature, vegetation and biomass through the multi-angle dual polarisation observations.

4.5.1 Project status

The industrial proposal from CASA EADS for the payload phase B has been received on 21st October and is under evaluation/negotiation. This timing should allow a seamless transition between the extended phase A and phase B.

System support studies with CNES and Alcatel are under preparation but first await an assessment whether a fourth gyro is needed for the PROTEUS AOCS. Depending on the outcome of this assessment, a major redirection of work might be needed.
The breadboarding activities in the frame of the MIRAS Demonstrator Pilot Projects (MDPP) 1 and 2 are about to be completed, with a full one arm deployment test on the one hand and an image validation test with a set of 12 receivers on the other hand.

Studies for the definition of the payload data ground segment and the scientific algorithms for instrument calibration and image reconstruction are about to be kicked-off. A first definition for the level 1 processor is supposed to follow shortly.

4.6- Next Explorer Core missions

A call of ideas for the new cycle of *Core* Missions was issued in June 2000, with deadline 1st September 2000, for scientists in the ESA Member States and Canada.

The general selection procedures, including a public consultation workshop (Granada III at end of October 2001) identified the missions to go into phase A study.

- EarthCARE, to study clouds, aerosols and radiation by a combination of active (radar and lidar) and passive instruments (multi-spectral imager, broadband radiometer and infrared Fourier transform spectrometer). This is to be implemented as a joint ESA/NASDA mission.

- SPECTRA, Surface Processes and Ecosystems Changes Through response Analysis, based on a payload including hyperspectral imager operating in the VNIR and SWIR and including thermal channels, to study the carbon, water and energy cycles.

- WALES, Water Vapour Lidar Experiment in Space, to provide accurate vertical profiles of water vapour concentration with high resolution by means of a differential absorption lidar.

A final selection of an ordered pair for implementation is expected in 2003, with launches in 2008 and 2010.

4.7- Next Explorer Opportunity missions

The call for ideas for the second cycle of Earth Explorer *Opportunity* Missions was released in early June 2001.These are intended to be very cost effective missions, implemented over short time scales, possibly exploiting new approaches to development and opportunities for international co-operation.

The evaluation of the twenty-five candidate proposals was completed. The Earth Sciences Advisory Committee recommended six candidates in order of priority: ACE+, EGPM, SWARM, SWIMSAT, TROC and CARBOSAT. Feasibility studies (Phase A) for the first three have started:

- ACE+ intended to provide accurate profiles of temperature and water vapour in the atmosphere exploiting radio-occultation methods. The nominal configuration includes a pair of satellites in each of two orbit planes at 90 deg inclination.
- EGPM would be the European contribution to the Global Precipitation Mission. It would consist of a satellite in sun-Synchronous orbit carrying a passive microwave radiometer optimized for Northern latitudes and, possibly, a single frequency rain radar.
- SWARM devoted to the study of the fine structure of the Earth's magnetic field and its components.

5. - EARTH WATCH

A programme was proposed to the ESA Council at ministerial level in November 2001.

5.1- Operational Meteorology and Climate Monitoring

Following a users workshop on November 2001, a joint ESA/Eumetsat plan for the consolidation of the user requirements for the post MSG mission has been agreed. ESA will initiate an study on sensor concepts.

Coordination with Eumetsat has also taken place regarding the payload of MetOp 3. In particular this refers to concept studies for an infrared imager.

5.2- Global Monitoring Missions

Ongoing activities refer to a visible-infrared imager applicable to ocean/land monitoring, and to innovative altimeter concepts.

5.3- Advance Imaging Missions

The implementation plans for TerraSAR (L band) and Fuegosat consolidation are on going.

5.4- GMES services element

GMES stand for the Global Monitoring for Environment and Security. GMES is a joint initiative of the European Space Agency and the European Commission.

In November 2001, the ESA Ministerial Council approved a new 5-year ESA programme dedicated to GMES, called the Earthwatch GMES Service Element (GSE for short). This is the very first programme dedicated to GMES.

GSE will deliver policy-relevant services to end-users, primarily (but not exclusively) from Earth Observation sources. GSE is a key element of GMES, because it will enable end-users to become key players in the move from present generation Earth Observation satellites to future European systems that will deliver vital information on global environment and security.

The ESA-EC co-operation for GMES is pursued as follows:

- Joint elaboration and agreement of all GMES policy papers and working documents
- Participation of both institutions in GMES groups
- Co-ordination of respective planning for the implementation of programmes content. EC: thematic projects from the 5^{th} and 6^{th} framework programs ESA: GMES service element (SE).

The GSE formally started in January 2002.The GMES Initial Period Final report is due by end 2003. It should pave the way for the GMES implementation period: 2004-2008.

6. - REFERENCES

Further information about the ENVISAT and Earth Explorers missions can be found on the following WWW addresses which offers the possibility to download many supporting relevant documentation:

http://www.esa.int
http://envisat.esa.int
http://www.estec.esa.nl/explorer/
http://earth.esa.int/gmes/